INCONGRUENT EVAPORATION EXPERIMENTS ON TROILITE AND ITS APPLICATION TO Fe/S FRACTIONATION IN THE PRIMORDIAL SOLAR NEBULA.

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It is expected that troilite (FeS) evaporates incongruently with metallic iron residue, and this may cause Fe/S fractionation in the primordial solar nebula. Evaporation experiments on troilite were carried out under H_2-rich conditions at total pressure 1.0-10^{-6} atm in order to elucidate kinetics of incongruent evaporation behavior of troilite in the primordial solar nebula. The fixed heating temperatures were 800-970°C for experiments at 1atm total pressure (partial hydrogen pressure ($p(H_2)$)=0.2-1.0 atm) and 900-970°C for experiments under low $p(H_2)$ conditions ($p(H_2)=10^{-3}$-10^{-6}atm).

Sulfur in troilite evaporates linearly with time because the evaporation reaction occurs on the surface of troilite with forming a porous residual layer of metallic iron. Taking individual processes, such as gas transfer, adsorption and desorption of gas, surface reaction and so on, into consideration based on the experimental results, it is concluded that the incongruent evaporation rates of troilite are controlled by the surface chemical reaction, and that the porous residual layer is formed due to fast diffusion of Fe in troilite. The evaporation flux of sulfur, J(S), show two types of dependence on $p(H_2)$; the rates at 1atm total pressure depend largely on $p(H_2)$ ($J(S) \propto \sim p(H_2)^{1.5}$), while those under the low $p(H_2)$ conditions have a little dependence on $p(H_2)$ ($J(S) \propto \sim p(H_2)^{0.1}$) (Fig.1). The both types of the evaporation rates show an Arrhenius relation. The activation energy of the rates at 1atm total pressure is ~80kJ/mol, while that under the low $p(H_2)$ conditions is ~340kJ/mol. These results indicate that the incongruent evaporation reaction of troilite changes in the present experimental conditions; sulfur evaporates from troilite as H_2S molecules ($FeS(s) + H_2(g) = Fe(s) + H_2S(g)$) under the high $p(H_2)$ conditions ($p(H_2)$=0.2-1.0atm), while as S_2 molecules ($FeS(s) = Fe(s) + 1/2S_2(g)$) under the low $p(H_2)$ conditions ($p(H_2)=10^{-3}$-10^{-6}atm) (Fig.1). Equilibrium calculations for gas species in the system Fe-S-H indicate that the evaporation reaction including $S_2(g)$ takes place metastably. The evaporation coefficients, a (= $J(S)_{meas.}/J(S)_{calc.}$), which represents degree of kinetic constrains of the evaporation (α 1), are an order of 10^{-4} and 0.2 for the evaporation reaction including $H_2S(g)$ and $S_2(g)$, respectively (Fig.1). The small values of a for the former reaction may be due to a very sluggish surface chemical reaction between H_2 molecules and troilite. This causes the metastable reaction with $S_2(g)$ occurred at $p(H_2)=10^{-3}$-10^{-6}atm.

The incongruent evaporation behavior of troilite in the primordial solar nebula were discussed by using the present experimental data (Fig.2). Troilite would evaporate as H_2S in the outer region of the active turbulent nebula (> about 1AU) and as S_2 in the inner region (< about 1AU). The local heating events might cause the evaporation of S_2 from troilite even in the outer region of the nebula. If we compare J(S) with the evaporation rates of metallic iron [1] (Fig.1), residual metallic iron evaporates little, and the incongruent evaporation of troilite can cause the Fe/S fractionation in the primordial solar nebula.

We applied the evaporation kinetics of troilite and metallic iron [1] to evaporation of dust particles which fall toward the proto sun in the turbulent primordial solar nebula using a recent dynamical model for the adiabatic nebula (Watanabe, unpublished). In this calculation, we assumed that dust particles (100μm or 1μm in size) did not grow by collision, evaporated gas and residual dust were not separated, and dust particles did not move in z-direction (from mid-plane to nebular surface) but moved only in r-direction (from outer part of the nebula to the sun). Calculations were carried out for both of dust particles which fall along the mid-plane and the surface. It was found in both cases (mid-plane and surface) that evaporation of iron and troilite particles would occur almost under equilibrium conditions although troilite particles could survive to inner region than that predicted by equilibrium calculations due to effects of evaporation kinetics. Since the temperatures of the surface are much lower than those of the mid-plane, dust particles can survive in inner region of the nebula near the surface than those near the mid-plane. This can cause Fe/S fractionation in a wide range of the nebula. Movement of dust particles along z-direction due to the turbulence and accompanied evaporation and condensation of dust should be examined.

[1] Tsuchiyama, A. and S.Fujimoto (1995), *Proceedings of the NIPR Symposium on Antarctic Meteorites*, **8**, 205-213.

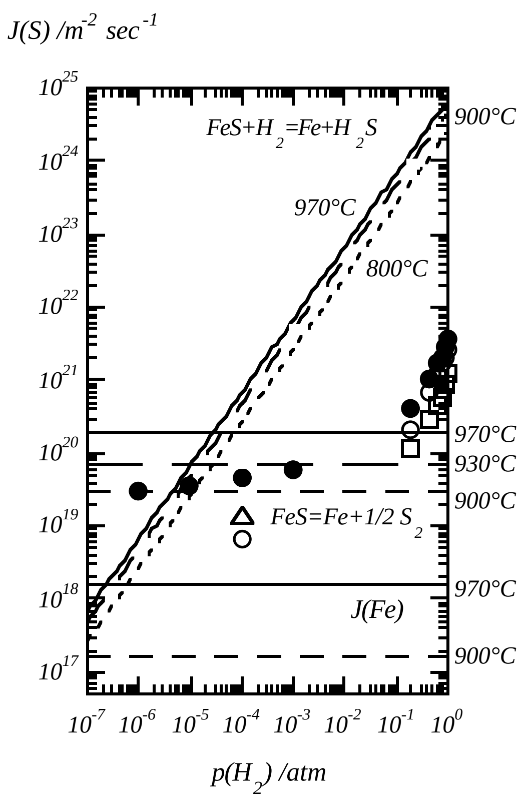

Fig.1 Evaporation flux of S, J(S), in the present experiments plotted against $p(H_2)$. Solid circles; 970°C, open triangles; 930°C, open circles; 900°C and open squares; 800°C. The ideal evaporation flux of H_2S (970°C, 900°C and 800°C), S_2 (970°C, 930°C and 900°C) and Fe (970°C and 900°C, J(Fe)) are also shown.

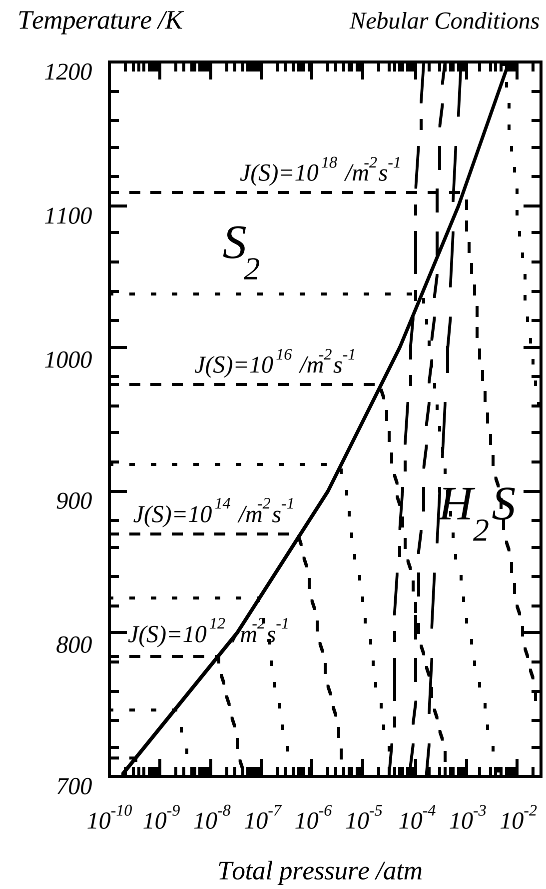

Fig.2 The p-T conditions under which H_2S and S_2 gas molecules are dominant species, respectively, for incongruent evaporation of troilite. The value of the evaporation coefficient, a is assumed based on the present experimental results $4x10^{-4}$ for the evaporation with H_2S, and 0.2 for the evaporation with S_2 under all calculated P-T conditions. Three dotted lines show the P-T conditions in the mid-plane of the nebula which have different turbulent viscosity (Watanabe, unpublished).